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Whats in a Fermi Bubble: a quasar episode in the Galactic centre

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Abstract.

Fermi bubbles, the recently observed giant (~ 10 kpc high) gamma-ray emitting lobes on either side of our Galaxy (Su et al. 2010), appear morphologically connected to the Galactic center, and thus offer a chance to test several models of super-massive black hole (SMBH) evolution, feedback and relation with their host galaxies. We use a physical feedback model (King 2003, 2010) and novel numerical techniques (Nayakshin et al. 2009) to simulate a short burst of activity in Sgr A*, the central SMBH of the Milky Way, ~ 6 Myr ago, temporally coincident with a star formation event in the central parsec. We are able to reproduce the bubble morphology and energetics both analytically (Zubovas et al. 2011) and numerically (Zubovas & Nayakshin, in prep). These results provide strong support to the model, which was also used to simulate more extreme environments (Nayakshin & Power 2010).

The AGN radiation pressure drives a wind with a momentum flux $\dot{M}_{\text{out}}v \simeq L_{\text{Edd}}/c$ with $v \simeq \eta c \simeq 0.1c$, where $\eta \simeq 0.1$ is the radiative efficiency (King 2003). This wind shocks against the surrounding gas (perhaps producing γ rays) and pushes it away, forming an outflow. In the Milky Way, the wind shock cannot cool outside $R_{\text{cool}} \sim 10$ pc and hence transfers most of the kinetic energy rate ($\sim 0.05L_{\text{Edd}}$) to the ambient gas (this is an energy-driven flow). Such an outflow, while driven, moves with a constant velocity $v_e \sim 1000$ km s⁻¹ (King et al. 2011). Once the quasar switches off, the shell coasts for an order of magnitude longer than the driving phase t_q , easily reaching radii of tens of kpc.

The outflow morphology can become non-spherical due to anisotropic matter distribution in the Galaxy, such as the dense gas in the Central Molecular Zone (CMZ) which is too heavy for even an energy-driven outflow to lift. This qualitatively explains the morphology of the *Fermi* bubbles. We use their observed and inferred properties to constrain the gas fraction (ratio of gas density to background potential density) in the Galaxy halo and the Sgr A* outburst duration (see Zubovas et al. 2011, for details):

$$f_g \lesssim 7 \cdot 10^{-3} l; \quad t_q > 2.5 \cdot 10^5 \text{ yr.} \quad (1)$$

We test the model numerically, using GADGET with a 'virtual particle' method of implementing wind feedback (Nayakshin et al. 2009). We embed the SMBH (which produces feedback for a time t_q) and CMZ into a spherically symmetric isothermal halo with $\sigma = 100$ km/s and a constant f_g . We vary the free parameters t_q and f_g .

Figure 1, left, shows that our model, with $t_q = 1$ Myr and $f_g = 10^{-3}$, can reproduce the morphology and size of the observed *Fermi* bubbles. The CMZ is perturbed but not dispersed by the wind and collimates the outflow into two cavities. The total energy content inside the cavities is a small fraction of the input and also agrees with

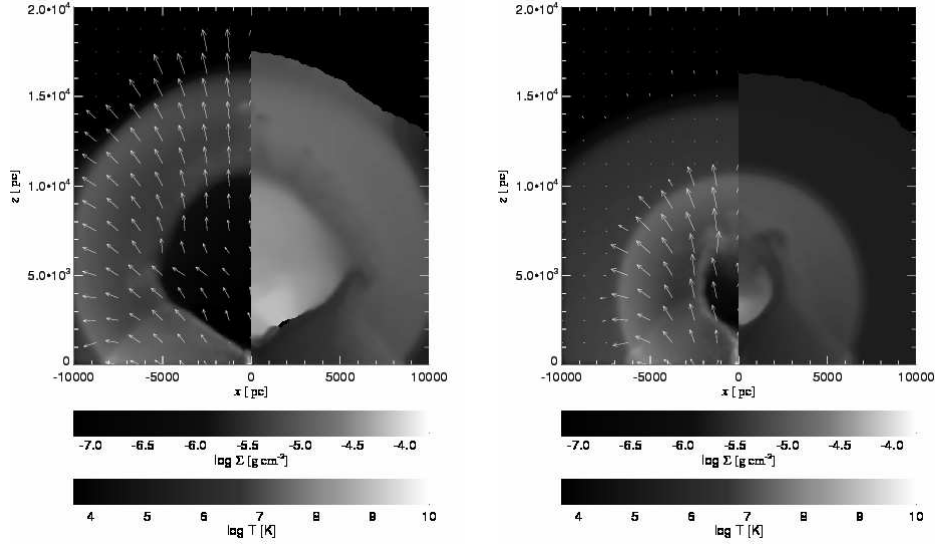


Figure 1. *Left:* Gas surface density (left) and temperature (right) at $t = 6$ Myr. The outflow is collimated and forms teardrop-shaped cavities with similar morphology to that of the observed *Fermi* bubbles. The simulation has $t_q = 1$ Myr, $f_{-3} = 1$. *Right:* Same as left, but $t_q = 0.3$ Myr. The cavity morphology is obviously inconsistent with observations. A change in f_g produces inconsistent results as well.

observational constraints. Figure 1, right, shows a simulation with $t_q = 0.3$ Myr, which produces bubbles clearly inconsistent with observations. We can thus put tight constraints on both parameters. We also require the CMZ mass to be $\simeq 10^8 M_\odot$, but its aspect ratio is not important. A physical heating-cooling prescription (Sazonov et al. 2005) does not change the results significantly either. Therefore our findings are quite robust with regard to the uncertainties involved in the initial conditions.

We have shown that our physically motivated SMBH wind feedback model can explain the *Fermi* bubbles. In addition, the same model works for quasars as their SMBHs establish the $M - \sigma$ relation and clear the host galaxies of gas (e.g. Nayakshin & Power 2010), suggesting there is no fundamental difference between the processes that were responsible for forming the galaxies at $z \gtrsim 2$ and the processes what is happening in local, mostly dormant, galactic nuclei.

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